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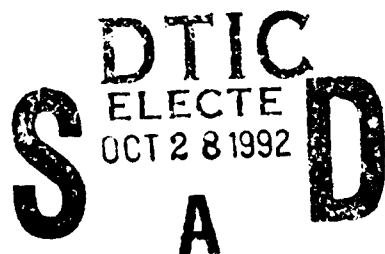
DATA MANIPULATION PACKAGE using PV~WAVE*

* Precision Visual's Workstation Analysis and Visualization Environment

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92-28349

15 October 1992

REPORT DOCUMENTATION PAGE

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	15 October 1992	FINAL Oct 91 - May 92

4. TITLE AND SUBTITLE	5. FUNDING NUMBERS
Data Manipulation Package Using PV-Wave * *Precision Visual's Workstation Analysis and Visualization Environment	PE - 63013N TA - R1947 WU - DN 157-019 C - N0014-89-C-2177

6. AUTHOR(S)

C.M. Siders, M.J. Parker, and
D.M. Bolling*

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)	8. PERFORMING ORGANIZATION REPORT NUMBER
Naval Research Laboratory Underwater Sound Reference Detachment P.O. Box 568337 Orlando, FL 32856-8337	NRL Memorandum Report 7105

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSORING/MONITORING AGENCY REPORT NUMBER
Naval Engineering Logitics Center P.O. Box 15467 Arlington, VA 22215	

11. SUPPLEMENTARY NOTES

*TRI/TESSCO, Inc., 9063 Bee Caves Road, Austin, TX 78733-6201

12a. DISTRIBUTION/AVAILABILITY STATEMENT	12b. DISTRIBUTION CODE
Approved for public release; distribution unlimited.	

13. ABSTRACT (Maximum 200 words)

The Data Manipulation Package (DMP) is a computer program that was written in the PV-WAVE command language. PV-WAVE is a high level data analysis and graphics programming language that is useful in data manipulation and graphical presentations. Unfortunately, to use the PV-WAVE language effectively, the user must be familiar with virtually hundreds of commands, functions, procedures and system variables. The DMP program was developed to facilitate the use of PV-WAVE by non-programmers by providing a menu-driven user interface. The capabilities supported by DMP are subdivided into four categories: plotting, curvefitting, data manipulation, and statistical calculations. Each of these categories has many options that are described in detail in this report. DMP is written to be as portable as the PV-WAVE program itself. DMP was written for use on Digital Equipment Corporation's VMS machines, as well as most UNIX based workstations.

14. SUBJECT TERMS			15. NUMBER OF PAGES
PV-WAVE Curve fitting	Plotting	Graphics	28
			16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UL

NSN 7540-01-280-5500

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DATA MANIPULATION PACKAGE USING PV~WAVE

INTRODUCTION

The Data Manipulation Package (DMP) is a computer program that was written in the PV~WAVE [1] command language. PV~WAVE is a high level data analysis and graphics programming language that is useful in data manipulation and graphical presentations. Unfortunately, to use the PV~WAVE language effectively, the user must be familiar with virtually hundreds of commands, functions, procedures and system variables. The DMP program was developed to facilitate the use of PV~WAVE by non-programmers by providing a menu-driven user interface. The capabilities supported by DMP are subdivided into four categories: plotting, curvefitting, data manipulation, and statistical calculations. Each of these categories has many options that are described in detail in this report.

DMP is written to be as portable as the PV~WAVE program itself. DMP was written for use on Digital Equipment Corporation's VMS machines, as well as most UNIX based workstations.

This report is not a user's manual, but rather serves as a general overview for the DMP program. The first section outlines the capabilities of DMP and the second section provides general operating instructions. The appendices contain information regarding the organization of DMP along with the subroutine descriptions. The computer code is available to all interested persons by requesting a copy from the following address:

> Naval Research Laboratory
> Underwater Sound Reference Detachment
> Attn: Code 5916 (C. M. Siders)
> P.O. Box 568337
> Orlando, FL 32856-8337

PROGRAM CAPABILITIES

DMP addresses the data analysis and graphical presentation requirements deemed most necessary in the everyday operation of a scientific laboratory using the PV~WAVE command language. PV~WAVE can perform many operations that are not included in the DMP interface; however, these options could be added to DMP if necessary. Figure 1 is a diagram illustrating the basic subdivisions of DMP; it does not indicate the program flow but organizes the capabilities of DMP in a logical manner. The first entry in the diagram in Fig. 1 is DATA ENTRY. There are three ways to bring data into DMP: read data from a file, generate data within the DMP program, and digitize data from a compatible tablet. Data entry, of course, must be performed before any other function. Once the data is entered it then must go through an "identification" phase. To identify the data simply means to select the column or columns necessary for the desired operation. For example, if a cartesian plot is required, the user must select the two columns that will be identified as the abscissa and the ordinate.
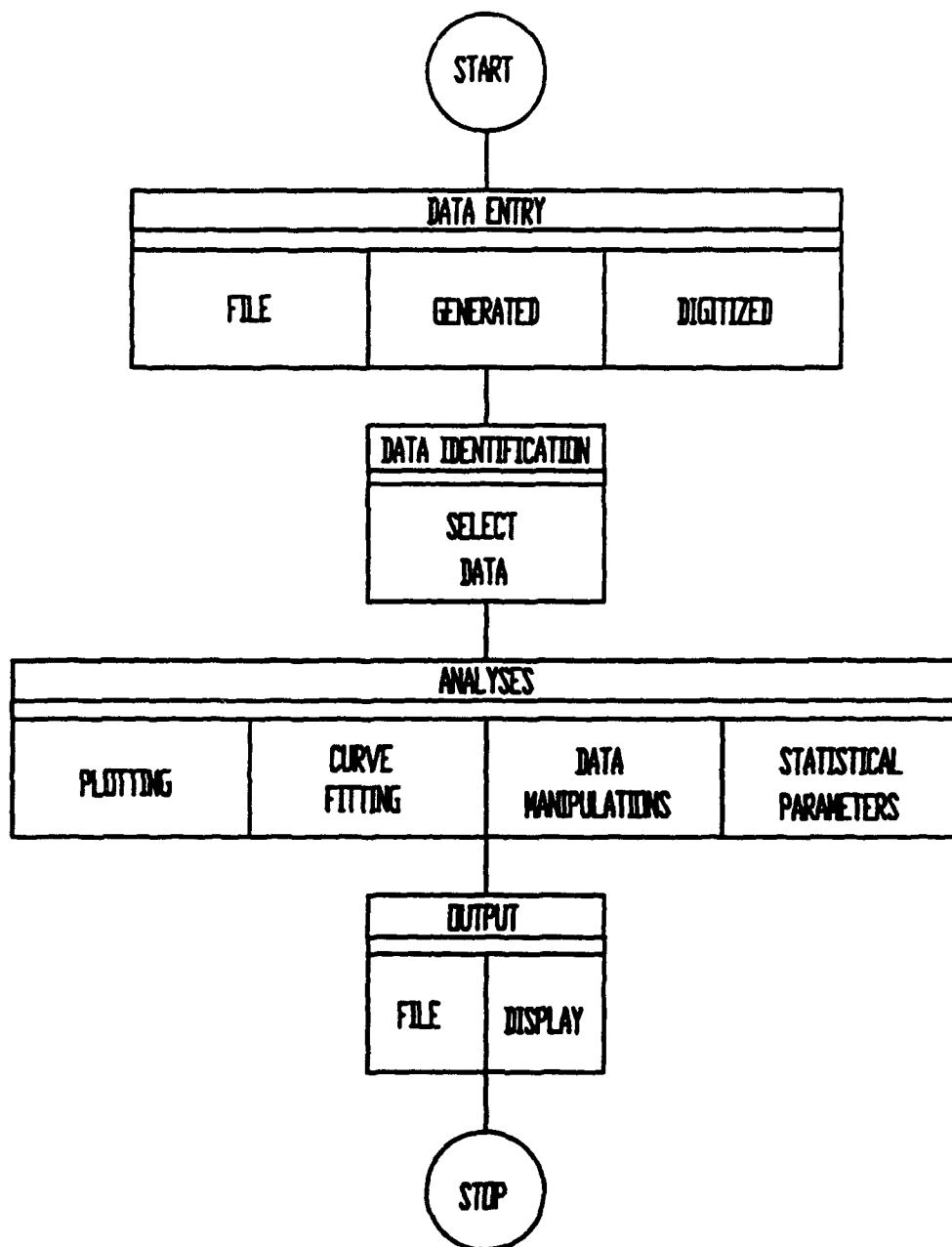
Fig. 1 - *Diagram depicting DMP capabilities*

After the data has been loaded and selected, the user has several options as shown in the "ANALYSES" entry in Fig. 1. The output for these procedures can be a visual display or a newly created file, or both. A description of the functionality of each of the specific routines will be described in more detail below.

Data Entry

One way of making data available for the DMP program is to load data from a file. This file should be columns of numbers (data set) stored in ASCII format. The numbers can be separated by commas or any number of blanks. Each row of data in the file must have the same number of columns. The program queries the user for the name of a file to be read. If the user is unsure of the filename(s) to be loaded, he may press the 'L' key to list all files in the current directory with a .dat extension. Once the filename has been entered, DMP loads the file and prints the number of rows and columns in the file on the screen. The user then has the opportunity to load more data or return to the main menu.

Data can also be generated with the DMP program illustrated by the "GENERATED" block in Fig. 1. This routine queries for a beginning value, an ending value, and the number of points. A single column of data is generated and can be stored permanently in a file. This data generation option may seem limited; however, with the available data manipulation capability, the user can execute a variety of operational forms. These general forms will be listed in the "DATA MANIPULATION" section in a latter part of this report.

The final method to input data is by digitizing points from a compatible tablet. DMP requires the user to mark the lower left-hand and upper right-hand corners of the drawing area. The lower left point should be placed at the minimum value of the abscissa and ordinate. The upper right point should be placed at he maximum value of both the abscissa and ordinate.

Data Selection

Once all the data files are loaded, the user is asked to "IDENTIFY" the data. To identify the data means to select the filename and column(s) that will be used for further procedures. All the PROCEDURES shown in Fig. 1 require that either one or two columns of data be selected.

Analyses

There are four main sections that will be discussed in detail: Plotting, Curvefitting, Data Manipulation and Statistical Evaluations. When a new data set is created from one of these sections, this does not imply that the data is permanently saved to a file. The name of this data set is used in the current session only, unless the user specifically chooses to save data to a file. If a graphic display is available, it may be viewed on the CRT screen or sent to a hard copy device. Appendix A details how the graphic output routines can be customized to the user's needs. Also, data can go from one routine to another. For example, loaded data can be curve fitted, then manipulated and finally plotted.

Plotting

The plotting capability in DMP was developed to give the amount of flexibility needed for publication quality displays without enduring extensive interactive computer sessions. This is done in DMP with menu-driven screens in which all the options have intrinsic defaults which allow the user to produce plots quickly by keeping the defaults; however, DMP allows the user to customize wherever needed. The customization parameters are used throughout the entire DMP session. There are two basic plotting capabilities: Polar Plotting and Cartesian Plotting.

Cartesian Plotting. Three forms of cartesian plotting include single plot, overplot, and multiple plot. "Single plot" produces one curve on a set of axes; "overplot" produces several curves on the same axes; and "multiple plot" produces two to four or smaller single-curved plots on a page.

```
               Single Plot Attributes

  1.)  Plot
  2.)  Plot title:

  3.)  X axis label:
  4.)  X axis type:      Linear
  5.)  X axis scaling:   Auto

  6.)  Y axis label:
  7.)  Y axis type:      Linear
  8.)  Y axis scaling:   Auto

  9.)  Line/symbol type:  Solid
 10.)  Line color:        White
 11.)  Output device:     VT340 Screen
 12.)  Printer parameters menu
 13.)  Mouse Utilities

  R.)  Return to previous menu
  Q.)  Quit from plotting package

Enter choice:
```

Fig. 2 - Standard plot menu viewed in an interactive DMP session.

Single Plot. Figure 2 shows the many customizing features available in the Single Plot option. Any text to the right of the colon is a default value. If a user simply wants a quick plot, he chooses entry 1)Plot. An autoscaled plot with no labels would appear on the screen. However, if customization is necessary, options 2 through 12 can be selected. Options 4 and 7 allow the user to choose between linear and logarithmic scaling. Options 5 and 8 allow the user to choose between autoscaling the data or manually entering minimum and maximum values for the abscissa and ordinate. Only the data in the prescribed range will be plotted. The line type (Option 9) can either be a line, a symbol, or a combination of the two. Option 12 allows the user to change plot dimensions and orientation for output sent to printers(landscape or portrait). Portrait mode is the default in which the top of the page is 8 1/2 " wide. Mouse utilities (option 13) requires that a mouse and mouse driver be installed. This option provides a cross-hair that moves and executes under control of the mouse. When the cross hairs are placed close to a point on the curve and the mouse is clicked, the values of the ordered pair will be returned. The user is also able to zoom on a portion of the plotting area and determine local minimums and maximums within the restricted zone. Auxiliary instructions are given on the last line of the screen. An example of a single plot is given in Fig. 3.
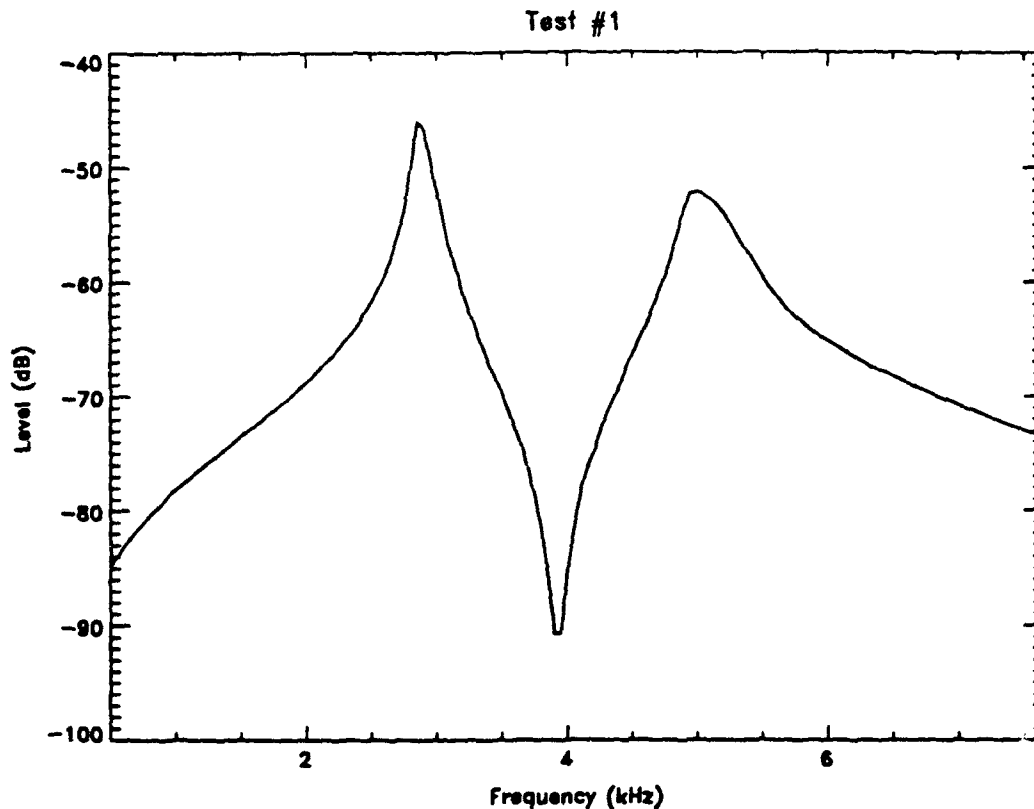
Test #1

Fig. 3 - Example of a "Single Plot" option.

Overplot. The overplot option requires that all the curves to appear on the same plot be marked by a toggle feature in DMP. The only other additional feature with this option is that the user can locate a legend anywhere in the plotting area by entering the coordinates of the lower left hand corner. The legend consists of the line type along with a short description as shown in Fig. 4. In order to access the legend, the user must enter the "Line Definition Menu". An example of an overplot with legend is shown in Fig. 5.

```
                        Line Definition Menu

        Abscissa              Ordinate
        Filename     Col     Filename     Col   Line Style   Color      Legend
        ---------------------------------------------------------------------------
    1.) 1675...........1     1675...........2   Solid        Blue       Freq. vs Amp
    2.) 1675...........1     1675...........3   Dashed       Red        Freq. vs Pha
    3.) POLAR..........1     POLAR..........3   Dash Dot     Green      Polar data

    4.) Return to previous menu

    Choose which line plot to modify:
```

Fig. 4 - DMP menu illustrating legend and line characteristics.

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N X N Array, Gap=0.02 in., f=fa + 90 kHz
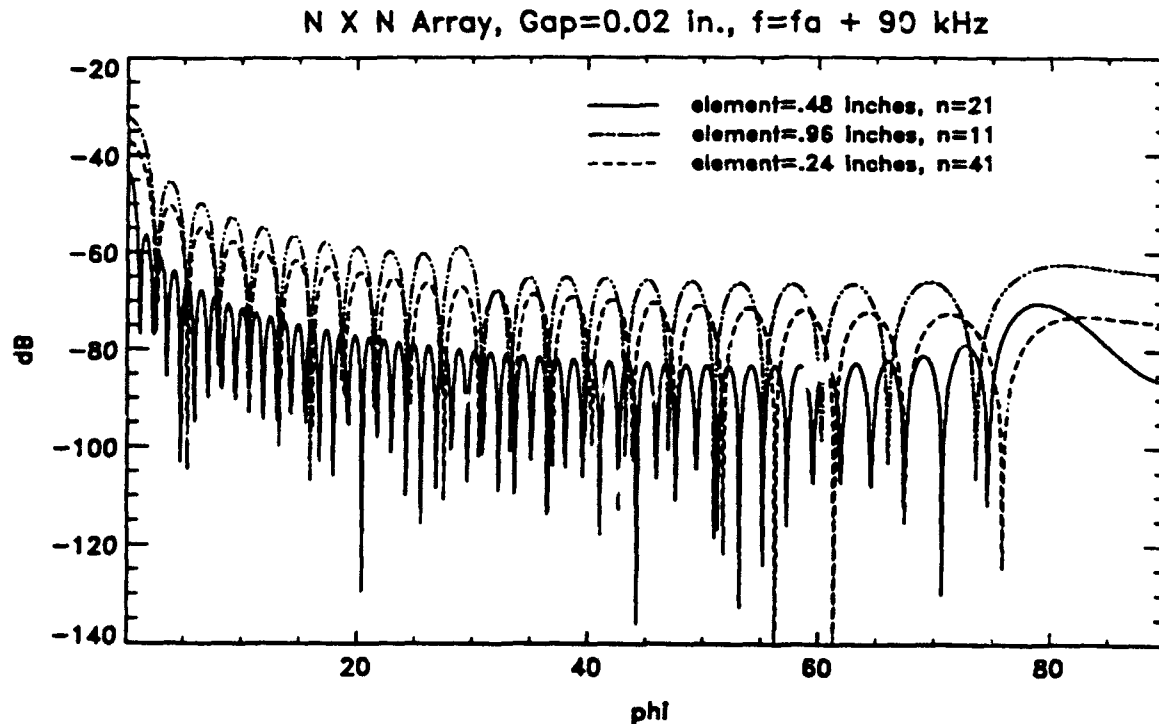
Fig. 5 - Example of "Overplot" with legend.

Multiple Plot. The multiple plot option allows the user to place several (2-4) smaller versions of a single plot on a page. These plots are selected by a toggle feature in DMP similar to that in the overplot option. The user can select the portrait or landscape mode and can choose a row major and column major priority. These priorities allow the user to arrange the plots by row first or by column first. Multiple plots in row major priority are shown in Fig. 6. Note the number in the upper left-hand corner shows the order in which the plots were selected.
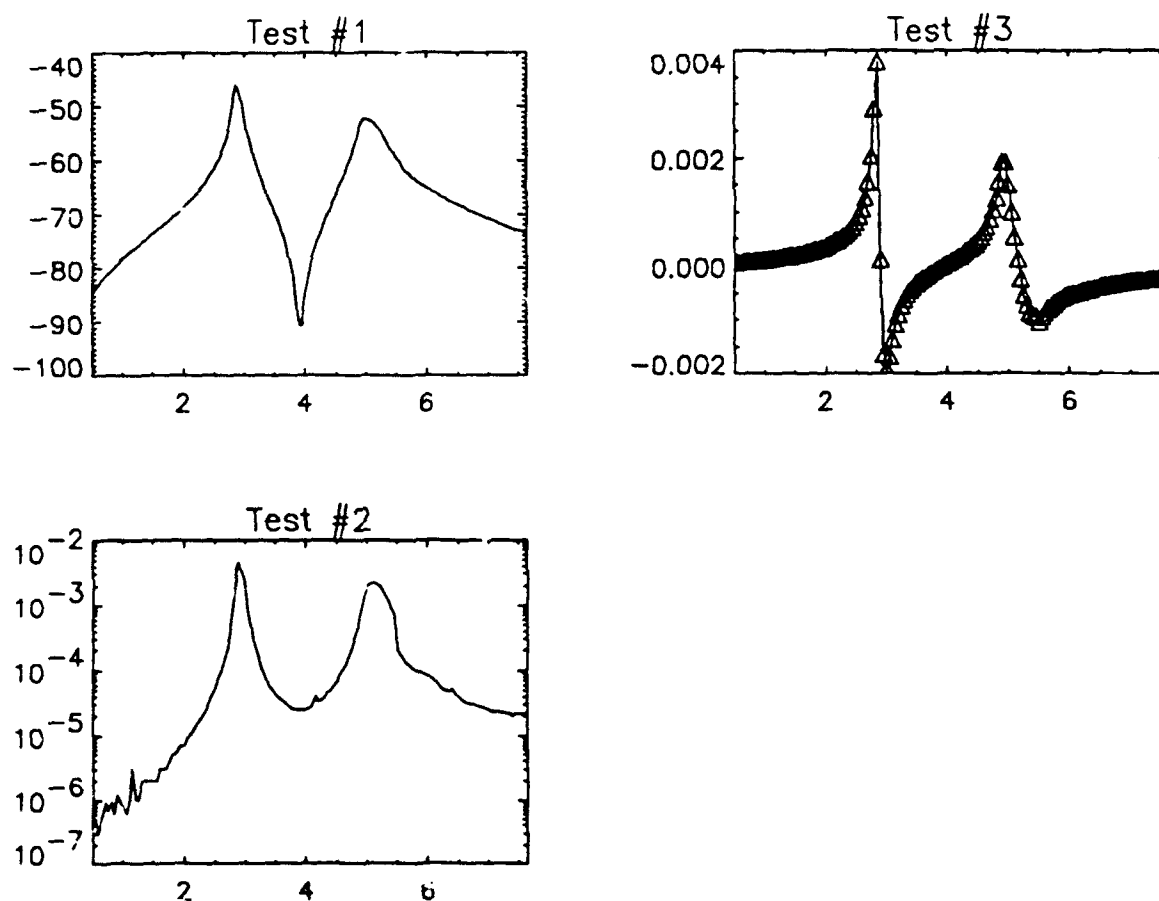
Fig. 6 - Example of "Multiplot Option" in row major priority.

Polar Plotting. The "Polar Plotting" option provides the capability of overplotting as shown in Fig. 7. The abscissa and ordinate for a polar plot must be the angle (default is radians) and the radius, respectively. DMP queries the user for the number of rings and the radial difference between rings. The user also has the option of setting any negative radial values to zero in the data file.
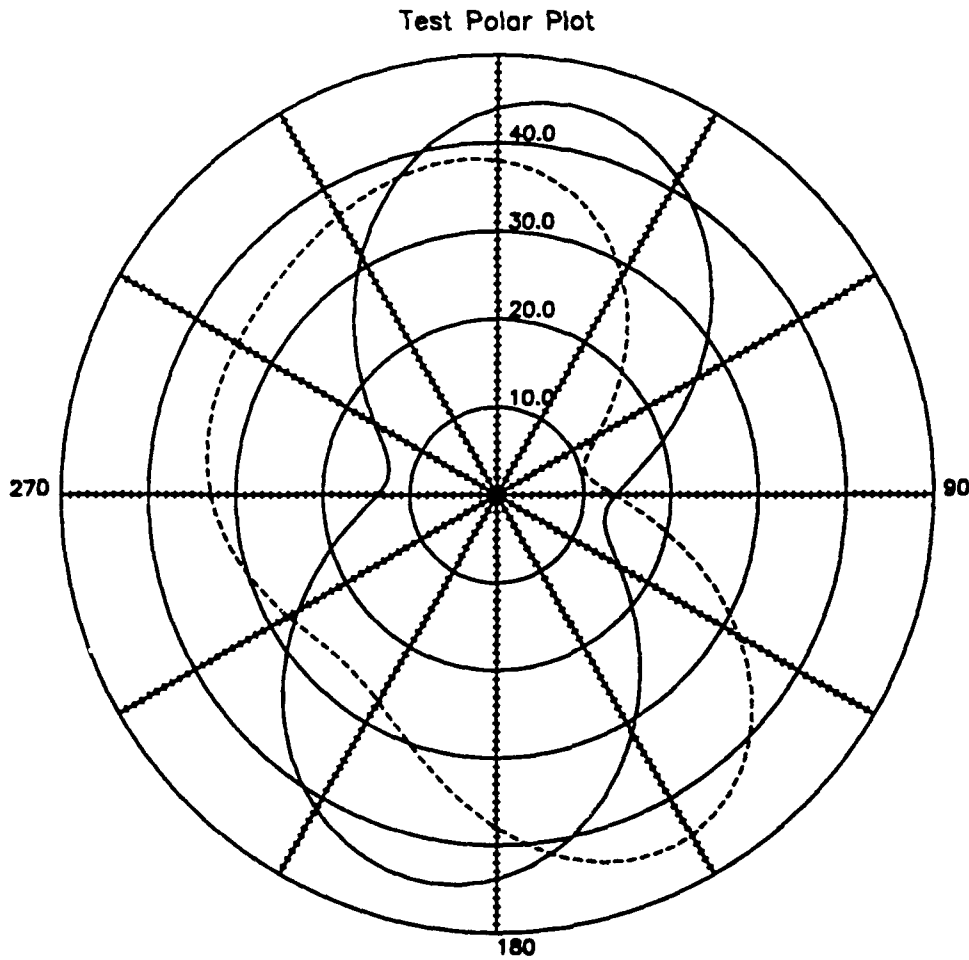
Test Polar Plot

Fig. 7 - Example of polar plot implementing overplot feature

Curvefitting

The user has a variety of functional forms to choose from for data curvefitting. All these forms allow the user to generate data beyond the range of the data that is being curvefitted. A Goodness of Fit Criterion is calculated and displayed for all the fitted data except the spline fit. The value for this parameter ranges from zero to one. The closer the parameter is to one the better the fit. The curvefitting forms include polynomial, rational fraction, exponential, logarithmic, and cubic spline. The data used for the rational fraction, exponential, and logarithmic curvefitting routines is automatically scaled to avoid any numerical overflow problems.

The polynomial fit includes all terms up to the eighth order. The user may choose an order less than eight, however, for each order all preceding terms exist. The rational fraction fit has the form:

$$\frac{c_1 + c_2 x + c_3 x^2 + c_4 x^3 + c_5 x^4 + c_6 x^5 + c_7 x^6}{c_8 + c_9 x + c_{10} x^2 + c_{11} x^3 + c_{12} x^4 + c_{13} x^5 + c_{14} x^6} \qquad (1)$$

Unlike with the polynomial fit, the user is allowed to omit any terms. The exponential and

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logarithmic fit have the following forms respectively:

$$c * \exp(-bx) + d \qquad (2)$$

and

$$a * \ln(bx) + d. \qquad (3)$$

The last curvefitting technique is a cubic spline interpolation. This method is useful in generating a smooth curve through a set of data points without being concerned with fitting to a particular form. Figure 8 is an example of a cubic spline fit through a given set of points.
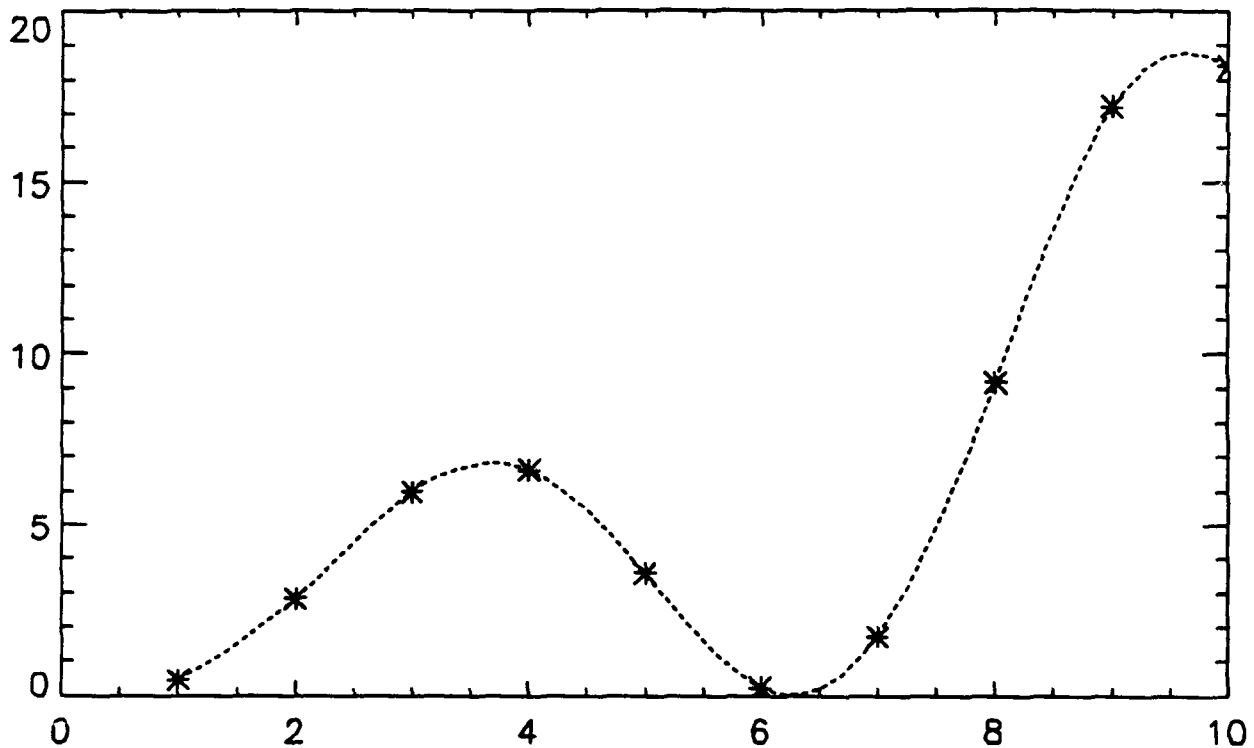

Fig. 8 - Example of cubic spline interpolation for a given set.

Data Manipulations

The DMP program allows the user to create a column of data by operating on one or two existing columns of data. The list of symbols supported are shown in Fig. 9.

```
SYMBOLS:
    A+B  : addition between two columns (of equal size)
    A-B  : subtraction of two columns (of equal size)
    3*A  : multiplication of a constant with a column
    A/5  : division of a column by a constant
    B^2  : raise each element in a column to a power
```

Fig. 9 - A list and description of the symbols available in DMP.

There are advanced operations that can be implemented. Figure 10 is a comprehensive list of functions that are available.

```
BUILT IN FUNCTIONS:
    ABS(x)      <- compute the absolute value of each element in x
    ACOS(x)     <- compute the arcosine of each element in x
    ALOG(x)     <- compute the natural logarithm of each element in x
    ALOG10(x)   <- compute the base 10 logarithm of each element in x
    ASIN(x)     <- compute the arcsine of each element in x
    ATAN(x)     <- compute the arctangent of each element in x
    AVG(x)      <- compute the average of the values of all elements in x
    COS(x)      <- compute the cosine of each element in x
    COSH(x)     <- compute the hyperbolic cosine of each element in x
    EXP(x)      <- compute the value e^x for each element in x
    FFT(x,dir)  <- compute the fast fourier transform of x.  A negative value for
                   dir transforms from the space domain to the frequency domain.  A
                   positive values for dir transforms from frequency to space
    MAX(x)      <- locates the largest value in x
    MEDIAN(x)   <- compute the median value in x
    MIN(x)      <- locates the smallest value in x
    SIN(x)      <- compute the sine of each element in x
    SINH(x)     <- compute the hyperbolic sine of each element in x
    SQRT(x)     <- compute the square root of each element in x
    SUM(x)      <- sums all values in x
    TAN(x)      <- compute the tangent of each element in x
    TANH(x)     <- compute the hyperbolic tangent of each element in x
```

Fig. 10 - A list and description of the functions available in DMP.

The "data manipulation" option is performed on a "selected" set of data, where the first column selected is labeled "a" and the second column selected is labeled "b." The data "selection" process could have occurred earlier in the same DMP session under a different procedure. For example, if the user wants to add 3sin of the first column of the selected data to the exponential of the second column of the selected data he would type the following command: $3 * \sin(a) + \exp(b)$.

In the data manipulation procedure, the user can use either column "a" or column "b", or both. If only one column is selected, then, of course, that column would be labeled column "a." The output of this data manipulation is temporarily stored in a user defined name. This data can also be permanently saved to a file.

Statistical Parameters

The statistical plotting package displays a frequency histogram (or relative frequency histogram) of data and calculates the following parameters: mean, median, mode, range, minimum, maximum, and standard deviation. These parameters are printed to the right of the histogram. The user also has the option of displaying these parameters in graphical form by overlaying them on the histogram as shown in Fig. 11. This option requires that one column of data be selected.

10
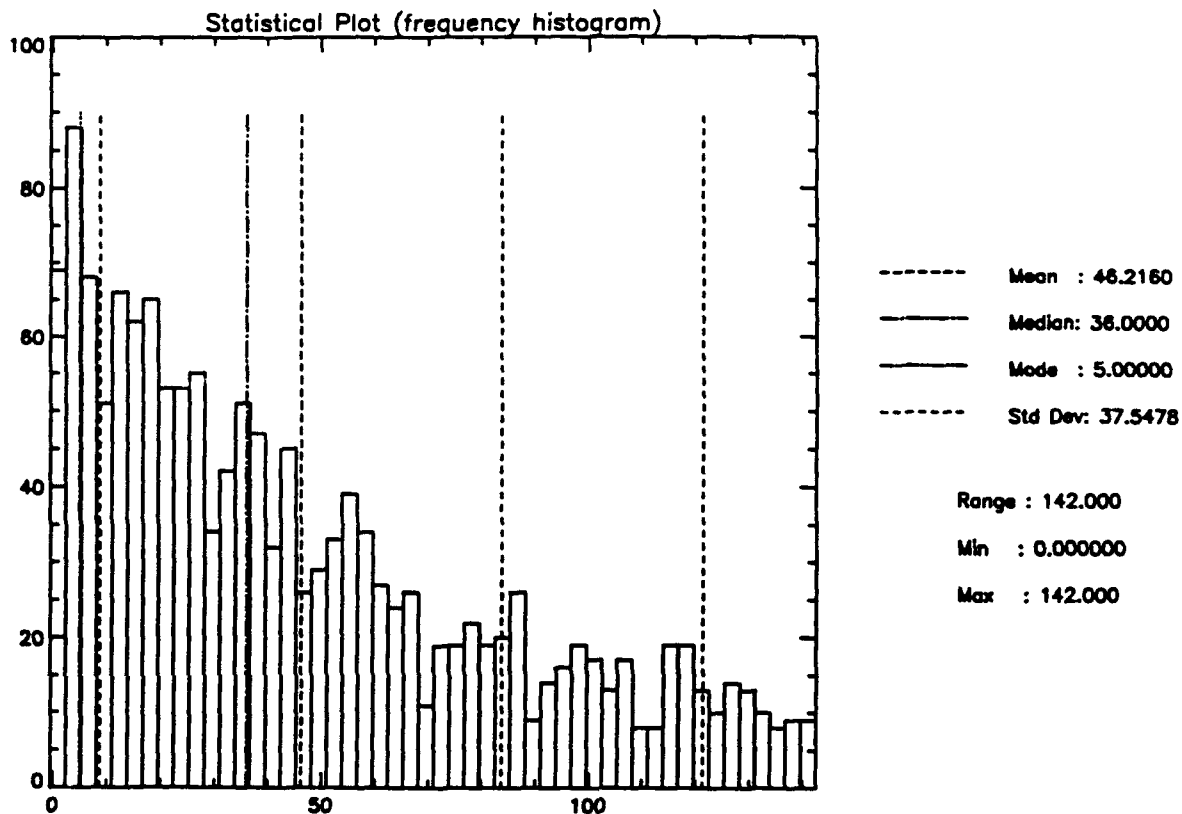
Fig. 11 - An example of a histogram with respective statistics.

INTERACTIVE SCREEN ORGANIZATION

This section gives the user an overview of the actual computer screen that may be observed in a typical interactive session. Figure 12 illustrates the hierarchy of menu screens in a block diagram format. Not all of the screens are included in Fig. 12 because either they do not contribute to the understanding of DMP or they were already described in the text. The words in each of the boxes in Fig. 12 are the actual titles of the interactive screens seen by the user.

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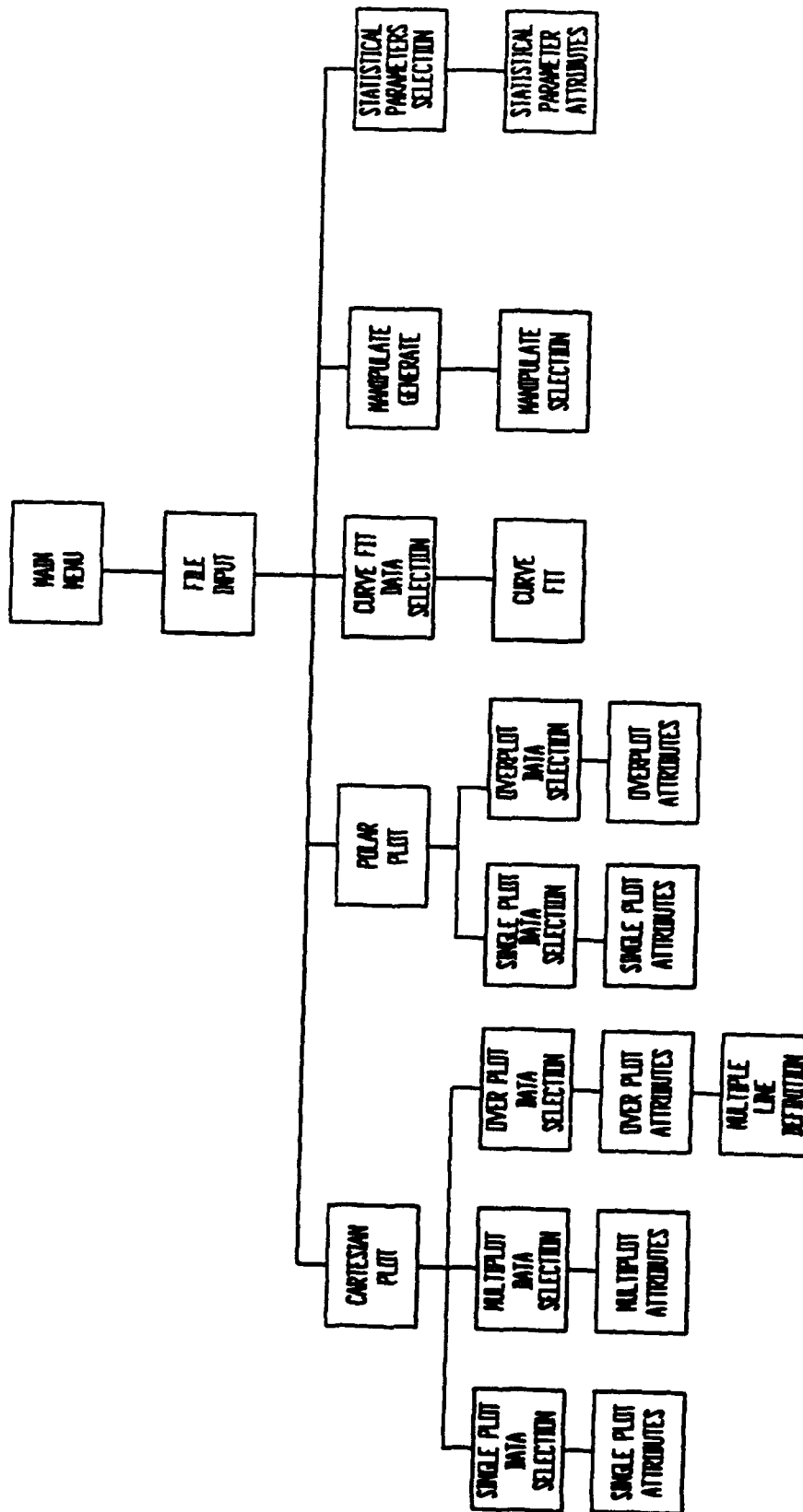
Fig. 12 - Hierarchy of interactive menu screens

ACKNOWLEDGEMENT

REFERENCES

1.   Precision Visuals, Inc., PV~WAVE Command Language V3.1 Technical Reference Manual, (Boulder, CO, 1988).

Appendix A

OUTPUT DEVICE CUSTOMIZATION

This appendix contains information useful in customizing DMP to support output devices not currently available. The devices supported by DMP include ReGIS terminals, X windows terminals, TEK4010 terminals, Talaris or QMS QUIC printers, and Postscript printers. Three PV~WAVE routines must be modified when adding a new printer definition which includes change_device.pro, setup_device.pro, and reset_device.pro.

Change_device.pro is a routine that provides the user with a list of output devices from which to select. This routine returns a number in the variable "device" (via the devcom common) that contains the user's selection.

The routine setup_device.pro redirects graphics to the correct output device with some minimal formatting. The formatting uses three parameters (wx, wy, and orient) that are passed via a common statement. The variables wx and wy are the length in inches of the abscissa and ordinate axis respectively. Orient determines if a display is landscape or portrait mode. Orient is set equal to 1 if the landscape mode is desired. If orient is set to any other value the graph will be in portrait mode.

The third routine, reset_device.pro, sends the file to the proper queue. This routine also sets the plot device back to its default value and closes any files created.

If it is necessary to add a device, be sure to add a unique device number. Users can change the order of the devices by changing the sequence given in the array variable "device_number" at the top of the program change_device.pro.

```
;**********************************************************************
 pro change_device, polar_option
;**********************************************************************
common devcom, device, device_name, wx, wy, orient

device_names = ['VT340 Screen',   'QMS Printer', 'X Window',   $
                'Tek4014 Screen', 'VT340 File',  'QMS File',   $
                'Tek4014 File',   'HPGL File', 'Pre-printed format',  $
                'PostScript Printer', 'PostScript File']

; device_number defines the order that the devices will appear in the menu.
; This way, you can add devices using higher numbers, and not affect the
; devices already defined.  Put your favorite output formats at the top.

device_number = [0, 9, 2, 1, 3, 4, 10, 5, 6, 7, 8]

temp = ''
t = 0
print, ' '
print, '     1.) VT340 Screen'
print, '     2.) PostScript Printer'
print, '     3.) X Window'
print, '     4.) QMS Printer'
print, '     5.) Tek4014 Screen'
print, '     6.) VT340 File'
print, '     7.) PostScript File'
```

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```
print, '    8.) QMS File'
print, '    9.) Tek4014 File'
print, '   10.) HPGL File'
if keyword_set(polar_option) then begin
    print, '   11.) Plot (pre-printed paper format on TALARIS1)'
endif
print, ' '
read, 'Choose format for graphics output:  ', temp
if temp ne '' then t = fix(temp)
if t ge 1 and t le 9 then begin
    device = device_number(t - 1)
    device_name = device_names(device)
endif
return
END


;************************************************************************
 pro setup_device, limited
;************************************************************************
; This routine should be customized so that files are sent to the proper
; printers.  Feel free to add new device codes.  You should also take a
; look at reset_device.pro if you are going to make modifications.

common devcom, device, device_name, wx, wy, orient

CASE device OF

; VT340 screen
   0: BEGIN
        set_plot, 'REGIS'
   END

; QMS printer
   1: BEGIN
        print, 'Creating PLOT.QMS and sending it to TALARIS1...'
        set_plot, 'QMS'
        if orient eq 1 then begin
            device, filename='plot.qms', /landscape, xoffset=.25, $
                    yoffset=.25,xsize=12.0,ysize=12.0,/inches
        endif else begin
            device, filename='plot.qms', /portrait, xoffset=.25, $
                    yoffset=.25,xsize=12.0,ysize=12.0,/inches
        endelse
        if not keyword_set(limited) then begin
            !p.thick = 1.1
            !x.thick = 1.1
            !y.thick = 1.1
            !y.margin = [4,3]
            tx = (wx * 2.54 * !d.x_px_cm) / !d.x_vsize
            ty = (wy * 2.54 * !d.y_px_cm) / !d.y_vsize
            if orient eq 1 then tx = tx * 1.012 else ty = ty * 1.012
            set_viewport,(1-tx)/2, 1-(1-tx)/2, (1-ty)/2, 1-(1-ty)/2
        endif
   END

; X Window
   2: BEGIN
        set_plot, 'X'
   END

; Tek4014 screen
   3: BEGIN
        set_plot, 'TEK'
   END

; VT340 graphics file
   4: BEGIN
```

```
            print, 'Creating PLOT.REG...'
            set_plot, 'REGIS'
            get_lun, lu
            openw, lu, 'PLOT.REG'
            device, plot_to=lu
        END


; QMS graphics file
    5: BEGIN
            print, 'Creating PLOT.QMS...'
            set_plot, 'QMS'
            if orient eq 1 then begin
                device, filename='plot.qms', /landscape, xoffset=.25, $
                        yoffset=.25,xsize=12.0,ysize=12.0,/inches
            endif else begin
                device, filename='plot.qms', /portrait, xoffset=.25, $
                        yoffset=.25,xsize=12.0,ysize=12.0,/inches
            endelse
            if not keyword_set(limited) then begin
                !p.thick = 1.1
                !x.thick = 1.1
                !y.thick = 1.1
                !y.margin = [4,3]
                tx = (wx * 2.54 * !d.x_px_cm) / !d.x_vsize
                ty = (wy * 2.54 * !d.y_px_cm) / !d.y_vsize
                if orient eq 1 then tx = tx * 1.012 else ty = ty * 1.012
                set_viewport,(1-tx)/2, 1-(1-tx)/2, (1-ty)/2, 1-(1-ty)/2
            endif
        END


; Tek4014 graphics file
    6: BEGIN
            print, 'Creating PLOT.TEK...'
            set_plot, 'TEK'
            get_lun, lu
            openw, lu, 'PLOT.TEK'
            device, plot_to=lu
        END


; HPGL graphics file
    7: BEGIN
            print, 'Creating PLOT.hpg...'
            set_plot, 'HP'
            device, filename='plot.hpg', /landscape, /inches
        END


; device 8 is prints a special polar plot file to the QMS printer.  This
; plot can be overlayed on top of special polar graph paper that we use
; for measurements so we can compare modeled data with actual measurements.

; PostScript printer
    9: BEGIN
            print, 'Creating PLOT.PS and sending it to POST$MODEL_LN05...'
            set_plot, 'PS'
            if orient eq 1 then begin
                device, filename='plot.ps', /landscape, xoffset=0.0, $
                        yoffset=11.0, xsize=11.0,ysize=8.5,/inches
            endif else begin
                device, filename='plot.ps', /portrait, xoffset=0.0, $
                        yoffset=0.0,xsize=8.5,ysize=11.0,/inches
            endelse
            if not keyword_set(limited) then begin
                !p.thick = 1.1
                !x.thick = 1.1
                !y.thick = 1.1
                !y.margin = [4,3]
                tx = (wx * 2.54 * !d.x_px_cm) / !d.x_vsize
                ty = (wy * 2.54 * !d.y_px_cm) / !d.y_vsize
```

```
                set_viewport,(1-tx)/2, 1-(1-tx)/2, (1-ty)/2, 1-(1-ty)/2
                print,(1-tx)/2, 1-(1-tx)/2, (1-ty)/2, 1-(1-ty)/2
                hak
            endif
        END

; PostScript graphics file
    10: BEGIN
        print, 'Creating PLOT.PS...'
        set_plot, 'PS'
        if orient eq 1 then begin
            device, filename='plot.ps', /landscape, xoffset=0.0, $
                    yoffset=0.0,xsize=11.0,ysize=8.5,/inches
        endif else begin
            device, filename='plot.ps', /portrait, xoffset=0.0, $
                    yoffset=0.0,xsize=8.5,ysize=11.0,/inches
        endelse
        if not keyword_set(limited) then begin
            !p.thick = 1.1
            !x.thick = 1.1
            !y.thick = 1.1
            !y.margin = [4,3]
            tx = (wx * 2.54 * !d.x_px_cm) / !d.x_vsize
            ty = (wy * 2.54 * !d.y_px_cm) / !d.y_vsize
            set_viewport,(1-tx)/2, 1-(1-tx)/2, (1-ty)/2, 1-(1-ty)/2
        endif
    END

    ELSE:   ; do nothing
ENDCASE
return
end


;**********************************************************************
 pro reset_device
;**********************************************************************
; This routine resets variables and/or closes files, setting the plot
; device to the default device (REGIS).  Feel free to modify this routine
; in order to use your particular graphics devices properly.  Be sure to
; look at setup_device.pro also.

common devcom, device, device_name, wx, wy, orient

CASE device OF

; VT340 screen
    0:BEGIN
        set_cursor, 23, 20
        hak, /mesg
        set_plot, 'REGIS'
    END

; QMS printer
    1:BEGIN
        !p.thick = 0
        !x.thick = 0
        !y.thick = 0
        !y.margin = [4,2]
        device, /close
        set_plot, 'REGIS'
        spawn, 'cprint plot.qms'
        print, 'Done.'
    END

; X window
    2:BEGIN
        set_plot, 'REGIS'
```

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```
            END

      ; Tek4014 screen
         3:BEGIN
            set_cursor, 23, 20
            hak, /mesg
            set_plot, 'REGIS'
         END

      ; VT340 graphics file
         4:BEGIN
            print, 'Done.'
            device, /close, plot_to=0
            close, lu
            set_plot, 'REGIS'
         END

      ; QMS graphics file
         5:BEGIN
            !p.thick = 0
            !x.thick = 0
            !y.thick = 0
            !y.margin = [4,2]
            print, 'Done.'
            device, /close
            set_plot, 'REGIS'
         END

      ; Tek4014 graphics file
         6:BEGIN
            print, 'Done.'
            device, /close, plot_to=0
            close, lu
            set_plot, 'REGIS'
         END

      ; HPGL graphics file
         7:BEGIN
            print, 'Done.'
            device, /close
            set_plot, 'REGIS'
         END

         9:BEGIN
            !p.thick = 0
            !x.thick = 0
            !y.thick = 0
            !y.margin = [4,2]
            device, /close
            set_plot, 'REGIS'
            spawn, 'post plot.ps'
            print, 'Done.'
         END

         10:BEGIN
            !p.thick = 0
            !x.thick = 0
            !y.thick = 0
            !y.margin = [4,2]
            device, /close
            set_plot, 'REGIS'
            print, 'Done.'
         END
         ELSE:
ENDCASE
return
end
```

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Appendix B

SUBROUTINE DESCRIPTIONS

This appendix contains a brief description of each subroutine and a table (Table B1) showing the interdependence of the various subroutines. The hierarchy of subroutines is from left to right in the table.

append_file: Appends the file and data names of a new data object to the structures maintaining this information.

append_p_info: Appends the default plotting parameters and data pairs to the structures maintaining this information for the standard and polar single plot routines.

cfit_interface: Allows the user to select one of several different curve fitting options and then performs the fit of the data to the specified model.

color_select: Allows the user to select a color for a plot line.

gauss2: Performs gaussian elimination with maximal pivoting the rational curvefitting routine.

genload: A general purpose function to load data files into a variable. For unformatted files, it asks the user about data types and number of columns. For formatted files, the number of columns and lines of data are determined automatically.

graphics: The main PV~WAVE program. Most of the higher level menus are here.

histgram2: Sets up and plots statistical information about a data set (histogram, mean, median, mode, standard deviation, range, min, and max).

histo_plot: Main menu controlling the statistical plots.

laminate: Appends a vector to an array. If the vector is smaller than the array, then it is padded with zero's to match the length of the array. If the array is smaller, then the array is extended in size by padding with zeros to match the length of the vector.

legend: The legend menu is here. It allows the user to define a legend for standard and polar overplots. The user has control over the position of the legend on the graph, text for each plot entry, line type, and color.

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line_descript: Lists the line styles, colors, and legends defined for all marked data pairs to be used in an overplot operation.

line_menu: Allows the user to select a line style, color, or legend for a marked data pair in an overplot. This routine calls line_descript to list the default values.

line_select: Allows the user to select a line style for a plot line in the histogram section.

loaded_files: Prints a list of the files loaded into the program. Each entry is separated by spaces

loader: Asks the user for a file name to load. It calls genload and can print out a list of data files in the current directory.

manip_help:	Lists the operations and functions supported by the manipulate operation.
manipulate:	Allows data to be created by applying mathematical operations to existing data.
mode:	Computes the statistical mode of a set of data
mouse_utilities:	Provides a series of options within the standard_plot menu that require a mouse. These options include finding the min/max of a data range, finding the closest point, and zoom.
name_check:	Prompts for a data name for newly created data and ensures that the name provided is unique.
output_select:	Allows the user to select a destination device for a plot.
polar_oplot:	Polar overplot menu and routines
polar_plot:	Plots one dataset assuming that the data is in polar coordinates.
polar_print:	Specialized polar print routine that scales the plot so that it can be overlaid on standard NRL polar graph paper.
printer_parms:	Allows the user to define the width and height in inches and whether the printout will be in landscape or portrait mode. Currently works only with QMS printers but should work with postscript printers also.
ratfit:	Performs rational fraction curvefitting.
ratsetup:	Allows the user to select the coefficients for fitting in the rational fraction curvefitting.
save_data:	Writes a newly created data object to a file.
select_hst:	Allows the user to mark any number of single data sets and to select one of these data sets for display in a histogram (statistical plot).
select_manip:	Allows the user to select one or two data columns to use for data manipulation. The user may also select a previous selection for re-use.
select_multi:	Similar to select_plot. It allows the user to select multiple sets of data that will be plotted together by either the overplot or multiplot functions.
select_plot:	Allows the user to create any number of paired data columns and then select one of these data sets for an upcoming operation.
show_manip_info:	Lists the data that has been previously selected for data manipulation.
show_selected:	Lists the data column pairs that have previously been marked as ordinate/abscissa or angle/range pairs.

standard_mplot: Standard multiplot menu allows the user to display more than one independent plot on one or more separate pages/screens.

standard_oplot: Standard overplot menu plots multiple data sets on one graph.

standard_plot: Standard plot menu only plots one data set.

xypick: Allows the user to select a column of data from one of the data sets currently loaded.

Table B1 - Subroutine Hierarchy

```
graphics
    ├─→ loaded_files
    ├─→ loader ──────────→ genload
    ├─→ append_file
    ├─→ cfit_interface ──┬─→ ratfit ──────────→ gauss2
    │                    └─→ name_check ───────→ ratsetup
    ├─→ save_data
    ├─→ name_check
    ├─→ select_plot ─────→ show_selected
    ├─→ manipulate ──────→ manip_help
    ├─→ xypick ──────────→ loaded_files
    ├─→ polarplot ──────┬─→ polarprint
    │                   ├─→ printer_parms
    │                   ├─→ printer_setup
    │                   ├─→ printer_reset
    ├─→ standard_plot────┴─→ mouse_utilities
    ├─→ select_multi ────→ show_selected
    ├─→ polar_oplot ────┬─→ polar_print
    │                   ├─→ linemenu ──────┬─→ line_descript
    │                   │                  └─→ show_selected
    │                   ├─→ printer_parms
    │                   ├─→ setup_device
    ├─→ standard_oplot──┴─→ reset_device
    ├─→ select_hst ──────→ show_hstselect
    ├─→ histo_plot ─────┬─→ histgram2 ────────→ mode
    │                   ├─→ color_select
    │                   ├─→ line_select
    │                   ├─→ setup_device
    │                   └─→ reset_device
    ├─→ laminate
    └─→ standard_mplot
```